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reviewer2@nptel.iitm.ac.in ▼

Courses » Estimation for Wireless Communications – MIMO/OFDM Cellular and Sensor Networks

Announcements Course Ask a Question Progress

Unit 5 - Week 4 - Least Squares (LS) Principle, Pseudo-Inverse, Properties of LS Estimate, Examples – Multi-Antenna Downlink and MIMO Channel Estimation



Course outline

How to Access the Portal ?

Week 1 - Basics of Estimation, Maximum Likelihood (ML)

Week 2 - Vector Estimation

Week 3 - Cramer-Rao Bound (CRB), Vector Parameter Estimation, Multi-Antenna Downlink Mobile Channel Estimation

Week 4 - Least Squares (LS) Principle, Pseudo-Inverse, Properties of LS Estimate, Examples – Multi-Antenna Downlink and MIMO Channel Estimation

Lecture 16 - Least Squares Solution Maximum Likelihood ML Estimate Pseudo Inverse

Lecture 17 - Properties of Least Squares Estimate – Mean

Assignment-4

The due date for submitting this assignment has passed. **Due on 2017-08-20, 23:59 IST.** As per our records you have not submitted this assignment.

1) Consider the maximum likelihood (ML) multi-antenna channel estimation **1 point** problem with N transmitted pilot vectors $\mathbf{x}(k) = [x_1(k), x_2(k), \dots, x_M(k)]^T$, $1 \leq k \leq N$ and N received symbols $y(1), y(2), \dots, y(N)$. Let the channel vector be $\mathbf{h} = [h_1, h_2, \dots, h_M]^T$. Let the pilot matrix be \mathbf{X} . The ML estimate of \mathbf{h} is,

$(\mathbf{X}^T \mathbf{X})^{-1} \mathbf{X}^T \mathbf{y}$

$(\mathbf{X}^T \mathbf{X})^{-1} \mathbf{X}^T \mathbf{h}$

$\mathbf{X}^{-1} \mathbf{y}$

$(\mathbf{X} \mathbf{X}^T)^{-1} \mathbf{X}^T \mathbf{y}$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$(\mathbf{X}^T \mathbf{X})^{-1} \mathbf{X}^T \mathbf{y}$

2) Consider a multi-antenna channel estimation scenario with $N = 4$ pilot vectors **1 point** $\mathbf{x}(1) = [3, 2]^T$, $\mathbf{x}(2) = [-2, 1]^T$, $\mathbf{x}(3) = [-1, -2]^T$, $\mathbf{x}(4) = [-1, 3]^T$. Let the corresponding received vector be $\mathbf{y} = [3, 2, 2, 1]^T$. Let the dB noise variance be -4.77 dB . The corresponding pilot matrix \mathbf{X} is,

$$\begin{bmatrix} 3 \\ 2 \\ -2 \\ 1 \\ -1 \\ -2 \\ -1 \\ 3 \end{bmatrix}$$

Covariance and Distribution
 Lecture 18 - Least Squares Multi Antenna Downlink Maximum Likelihood Channel Estimation

Lecture 19 - Multiple Input Multiple Output MIMO Channel Estimation - Least Squares Maximum Likelihood ML

Lecture 20 - Example - Least Squares Multiple Input Multiple Output MIMO Channel Estimation

Quiz : Assignment-4

Assignment-4 Solution

Week 5 - Inter Symbol Interference, Channel Equalization, Zero-forcing equalizer, Approximation error of equalizer

Week 6 - Introduction to Orthogonal Frequency Division Multiplexing (OFDM) and Pilot Based OFDM Channel Estimation, Example

Week 7 - OFDM - Comb Type Pilot (CTP) Transmission, Channel Estimation in Time/ Frequency Domain, CTP Example, Frequency Domain Equalization (FDE), Example-FDE

Week 8 - Sequential Least Squares (SLS) Estimation -

$$\begin{bmatrix} 3 & 2 \\ -2 & 1 \\ -1 & -2 \\ -1 & 3 \end{bmatrix}$$

$$\begin{bmatrix} 3 & -2 & -1 & -1 \\ 2 & 1 & -2 & 3 \end{bmatrix}$$

$$[3 \ 2 \ -2 \ 1 \ -1 \ -2 \ -1 \ 3]$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\begin{bmatrix} 3 & 2 \\ -2 & 1 \\ -1 & -2 \\ -1 & 3 \end{bmatrix}$$

3) Consider a multi-antenna channel estimation scenario with $N = 4$ pilot vectors **1 point**
 $\mathbf{x}(1) = [3, 2]^T$, $\mathbf{x}(2) = [-2, 1]^T$, $\mathbf{x}(3) = [-1, -2]^T$, $\mathbf{x}(4) = [-1, 3]^T$. Let the corresponding received vector be $\mathbf{y} = [3, 2, 2, 1]^T$. Let the dB noise variance be $-4.77dB$. The pseudo-inverse of the pilot matrix \mathbf{X} is,

$$\frac{1}{87} \begin{bmatrix} 16 & -13 & -4 & -9 \\ 7 & 7 & -9 & 16 \end{bmatrix}$$

$$\frac{1}{87} \begin{bmatrix} -11 & 17 & 14 & 21 \\ 5 & -27 & 9 & 12 \end{bmatrix}$$

$$\frac{1}{87} \begin{bmatrix} 42 & 32 \\ -29 & 16 \\ -21 & -72 \\ -16 & 38 \end{bmatrix}$$

$$\frac{1}{87} \begin{bmatrix} 33 & -23 & 8 & 25 \\ 12 & -14 & 34 & -45 \end{bmatrix}$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\frac{1}{87} \begin{bmatrix} 16 & -13 & -4 & -9 \\ 7 & 7 & -9 & 16 \end{bmatrix}$$

4) Consider a multi-antenna channel estimation scenario with $N = 4$ pilot vectors **1 point**
 $\mathbf{x}(1) = [3, 2]^T$, $\mathbf{x}(2) = [-2, 1]^T$, $\mathbf{x}(3) = [-1, -2]^T$, $\mathbf{x}(4) = [-1, 3]^T$. Let the corresponding received vector be $\mathbf{y} = [3, 2, 2, 1]^T$. Let the dB noise variance be $-4.77dB$. The estimate of the channel vector \mathbf{h} is,

$$\frac{1}{87} \begin{bmatrix} 68 \\ 32 \end{bmatrix}$$

$$\frac{1}{87} \begin{bmatrix} 21 \\ 17 \end{bmatrix}$$



Scalar/ Vector
Cases,
Applications -
Wireless Fading
Channel
Estimation, SLS
Example

$$\frac{1}{87} \begin{bmatrix} -12 \\ 45 \end{bmatrix}$$

$$\frac{1}{87} \begin{bmatrix} 5 \\ 33 \end{bmatrix}$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\frac{1}{87} \begin{bmatrix} 5 \\ 33 \end{bmatrix}$$

5) Consider a multi-antenna channel estimation scenario with $N = 4$ pilot vectors $\mathbf{x}(1) = [3, 2]^T$, $\mathbf{x}(2) = [-2, 1]^T$, $\mathbf{x}(3) = [-1, -2]^T$, $\mathbf{x}(4) = [-1, 3]^T$. Let the corresponding received vector be $\mathbf{y} = [3, 2, 2, 1]^T$. Let the dB noise variance be $-4.77dB$. The covariance of the ML estimate is, 1 point

$$\frac{1}{261} \begin{bmatrix} 5 & 0 \\ 0 & 5 \end{bmatrix}$$

$$\begin{bmatrix} \frac{1}{3} & 0 \\ 0 & \frac{1}{3} \end{bmatrix}$$

$$\frac{1}{261} \begin{bmatrix} 6 & 0 \\ 0 & 5 \end{bmatrix}$$

$$\frac{1}{261} \begin{bmatrix} 6 & -1 \\ -1 & 5 \end{bmatrix}$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\frac{1}{261} \begin{bmatrix} 6 & -1 \\ -1 & 5 \end{bmatrix}$$

6) Consider a multi-antenna channel estimation scenario. In general, when are the estimation errors of the various channel coefficients uncorrelated for a scenario with IID noise samples of variance σ^2 each? 1 point

- When the pilot matrix is square
- When the pilot matrix is invertible
- When the columns of pilot matrix are orthogonal
- None of the above

No, the answer is incorrect.

Score: 0

Accepted Answers:

When the columns of pilot matrix are orthogonal

7) Consider a multi-antenna channel estimation scenario with $N = 3$ pilot vectors $\mathbf{x}(1) = [1, 2]^T$, $\mathbf{x}(2) = [3, -1]^T$, $\mathbf{x}(3) = [1, 1]^T$. Let the corresponding received vector be $\mathbf{y} = [2, 1, 2]^T$. The pseudo-inverse of the pilot matrix \mathbf{X} is, 1 point

$$\begin{bmatrix} \frac{1}{11} & \frac{3}{11} & \frac{1}{11} \\ \frac{1}{3} & -\frac{1}{6} & \frac{1}{6} \end{bmatrix}$$



$$\begin{bmatrix} 1 & 3 & 1 \\ 2 & -1 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \frac{2}{11} & -\frac{3}{11} & -\frac{1}{11} \\ \frac{1}{3} & \frac{1}{6} & -\frac{1}{6} \end{bmatrix}$$

$$\begin{bmatrix} \frac{2}{6} & -\frac{3}{6} & -\frac{1}{6} \\ \frac{1}{11} & \frac{1}{11} & -\frac{1}{11} \end{bmatrix}$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\begin{bmatrix} \frac{1}{11} & \frac{3}{11} & \frac{1}{11} \\ \frac{1}{3} & -\frac{1}{6} & \frac{1}{6} \end{bmatrix}$$

8) Consider a multi-antenna channel estimation scenario with $N = 3$ pilot vectors **1 point** $\mathbf{x}(1) = [1, 2]^T$, $\mathbf{x}(2) = [3, -1]^T$, $\mathbf{x}(3) = [1, 1]^T$. Let the corresponding received vector be $\mathbf{y} = [2, 1, 2]^T$. The ML estimate of the channel is given as

$$\begin{bmatrix} \frac{7}{11} \\ \frac{5}{6} \end{bmatrix}$$

$$\begin{bmatrix} \frac{6}{11} \\ \frac{1}{6} \end{bmatrix}$$

$$\begin{bmatrix} \frac{5}{6} \\ \frac{1}{11} \end{bmatrix}$$

$$\begin{bmatrix} \frac{5}{6} \\ -\frac{1}{11} \end{bmatrix}$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\begin{bmatrix} \frac{7}{11} \\ \frac{5}{6} \end{bmatrix}$$

9) Consider a multi-antenna channel estimation scenario with $N = 3$ pilot vectors **1 point** $\mathbf{x}(1) = [1, 2]^T$, $\mathbf{x}(2) = [3, -1]^T$, $\mathbf{x}(3) = [1, 1]^T$. Let the corresponding received vector be $\mathbf{y} = [2, 1, 2]^T$. Let the dB noise variance be $3dB$. The covariance of the ML estimate is,

$$\begin{bmatrix} \frac{1}{11} & 0 \\ 0 & \frac{1}{6} \end{bmatrix}$$

$$\begin{bmatrix} \frac{2}{11} & 0 \\ 0 & \frac{2}{6} \end{bmatrix}$$

$$\begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix}$$



$$\begin{bmatrix} 2 & 2 \\ 2 & 2 \end{bmatrix}$$

No, the answer is incorrect.

Score: 0

Accepted Answers:

$$\begin{bmatrix} \frac{2}{11} & 0 \\ 0 & \frac{2}{6} \end{bmatrix}$$

10 Consider a multi-antenna channel estimation scenario with $N = 3$ pilot vectors **1 point**
 $\mathbf{x}(1) = [1, 2]^T$, $\mathbf{x}(2) = [3, -1]^T$, $\mathbf{x}(3) = [1, 1]^T$. The correlation between the estimation errors of the individual channel coefficients is,

- 1
 11
 6
 0

No, the answer is incorrect.

Score: 0

Accepted Answers:

0



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